

ENGINE GOVERNING SYSTEMS

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ENGINE GOVERNING SYSTEMS

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INTRODUCTION

ELECTRONIC CIRCUITS continue to become faster, smaller and less expensive, with the recent rapid advances in the state-of-the-art showing no signs of slowing. The last decade has seen the replacement of existing controls by electronic systems at an unprecedented rate. Some examples being:

- Calculators
- Wrist Watches
- Arcade Games
- Domestic Appliances

- Industrial Process Controls
- Elevator Controls
- Military Missiles
- Passenger Car Fuel Systems
- Jet Engine Fuel Systems
- Gas Turbine Fuel Systems

The performance and flexibility gains with electronic systems are so great that manufacturers wishing to stay competitive have had to introduce this technology in a very short space of time.

DESCRIPTION

BASIC ENGINE GOVERNOR SYSTEM COMPARISON

Engine control systems can be subdivided into three (3) separate functions:

- Sensing: Pressure, speed, temperature, etc.
- Computing: Action to be taken.
- Acting: Physical system response.

Hydromechanical systems typically combine these requirements such that they cannot be clearly separated. For example, the fuel pump governor schematic shown in Figure 1 uses flyweights for speed sensing, the flyweight and governor spring combination for computation, and the flyweights to provide the force to position the spool valve to control fuel flow rate. The resultant system is very cost effective but has limited performance and flexibility.

Electronic controls by comparison typically maintain separate, the 3 clearly defined functions, each part of the control system being designed to fulfill one specific task.

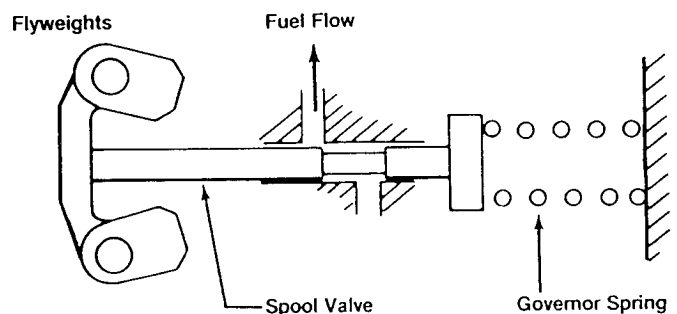


Fig. 1 - Hydromechanical Governor Schematic

- The speed sensor senses the actual speed.
- The speed controller is set with the desired speed. The controller computes the error between desired and actual speed and adjusts the actuator current.
- The actuator moves the fuel control to adjust engine power.

The electric governor speed sensor consists of a magnetic pickup, usually mounted in the flywheel housing in close proximity to the ring gear teeth on the flywheel. As the gear teeth pass by the end of the magnetic sensor, an AC sine wave is generated; the frequency to the signal is proportional to engine speed.

At the speed controller, the AC signal is rectified (changed into DC) and compared with the desired speed D.C. voltage setting. The output voltage to the actuator is proportional to the difference between the set speed D.C. voltage and the speed sensor D.C. voltage. The actuator is controlled by pulse width modulating battery voltage.

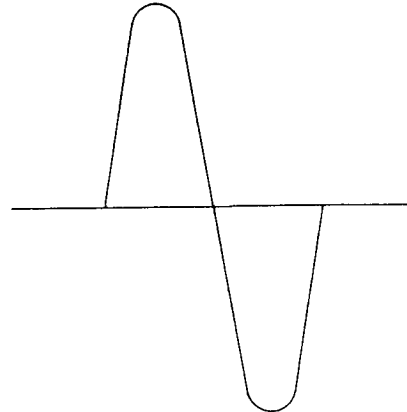


Fig. 3 - Magnetic Pickup Output Waveforms

The actuator controls the fuel pump delivery. It is a fast-acting displacement driver whose motion is proportional to current flow.

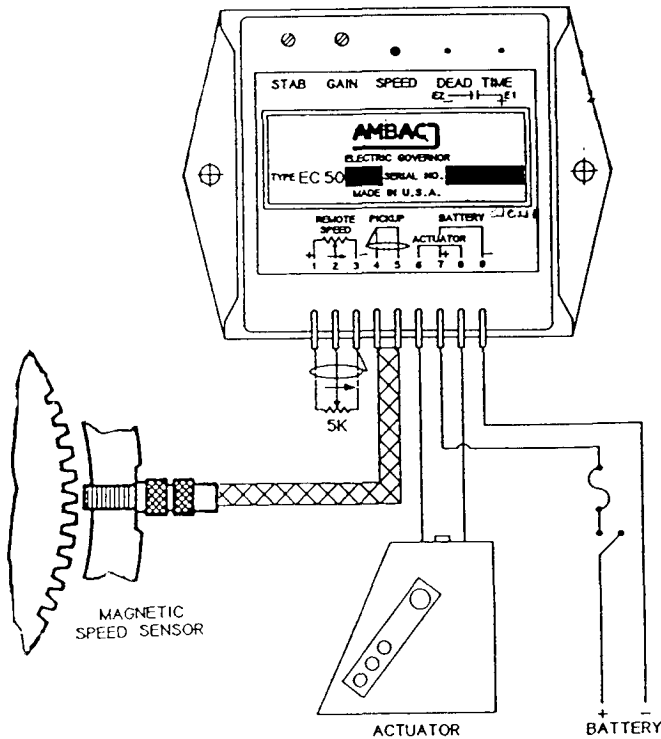


Fig. 2 - System Configuration

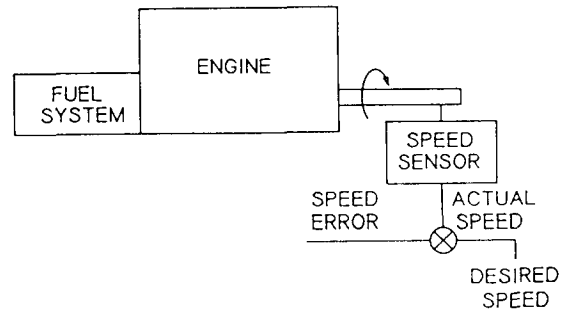


Fig. 4 - Speed Error vs. Desired Speed

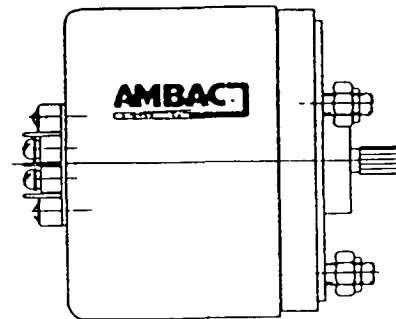


Fig. 5 - AGK 500 Actuator

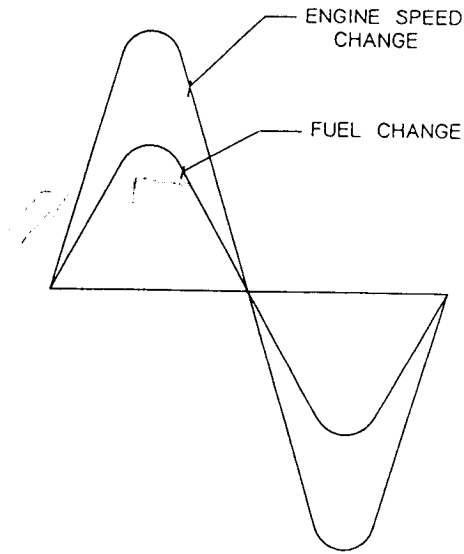


Fig. 6 - Engine Response
High No Load Gain

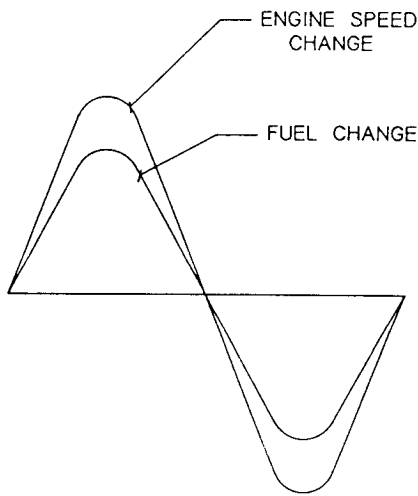


Fig. 7 - Engine Response
Low Full Load Gain

Figure 6 shows high gain of the engine when carrying no load.

Figure 7 shows low gain of the engine when loaded. Gain of the engine varies with load.

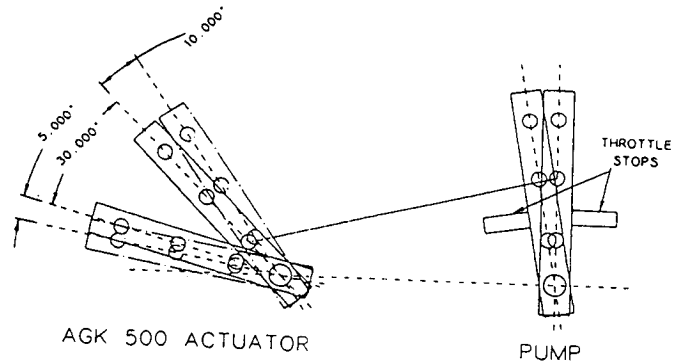


Fig. 8 - Non-Linear linkage

Figure 8 shows a non-linear linkage between actuator and fuel system. This linkage has low gain at low fuel (low load) and higher gain at high fuel (high load). Linkage gain is matched to engine gain to provide a system which has a relatively constant gain with varying load.

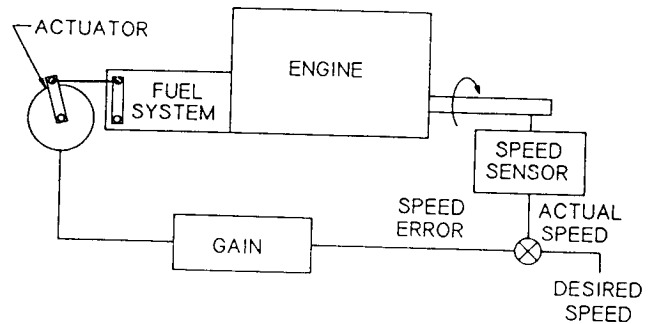


Fig. 9 - Simple Proportional Governor

Figure 9 shows an engine operating in closed loop with the speed sensor signal. With a change in engine load, it is necessary to determine the magnitude of the fuel delivery correction. If the engine has been loaded to reduce speed, the fuel rate needs to be increased; if the speed increased, the fuel rate needs to be reduced.

Small fuel changes being made for small errors and larger fuel changes for larger errors. If we do just this, it is called PROPORTIONAL GAIN (see Figure 10).

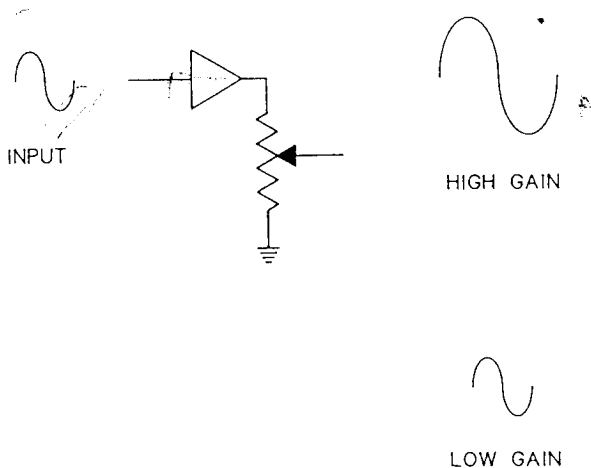


Fig. 10 - Gain Adjustment

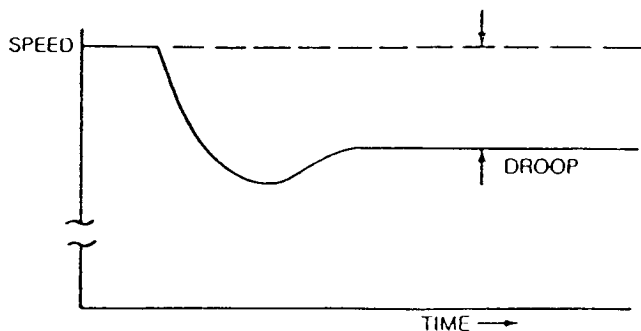


Fig. 11 - Speed vs. Droop

Effect of GAIN on Speed Error.

The GAIN circuit amplifies the error signal. When the GAIN is increased, the error signal size is increased and more corrective action is taken and the response is larger. When the GAIN is reduced, the error signal is reduced so less corrective action is taken and response is less.

GAIN is not adjustable on mechanical and hydraulic governors. To change GAIN, one must change the governor spring rate or the ports. For example, round ports versus slotted ports.

Electric governors provide adjustable GAIN. This is achieved by changing the amplification of the speed error. A screw adjustable potentiometer is used to control this. Although the configuration of the various speed control units are different, all units identify the screw with the label "GAIN".

A PROPORTIONAL GAIN governor is a DROOP governor because a proportional governor changes fuel delivery with respect to the size of the speed error.

The GAIN cannot be increased until there is no error, since this would require infinite GAIN. Governors with excessive GAIN become unstable. There will always be some change in speed with a change in load when using a simple proportional governor. This change in speed is called DROOP and is usually expressed at a percentage of the set speed. (see Figures 11 and 12).

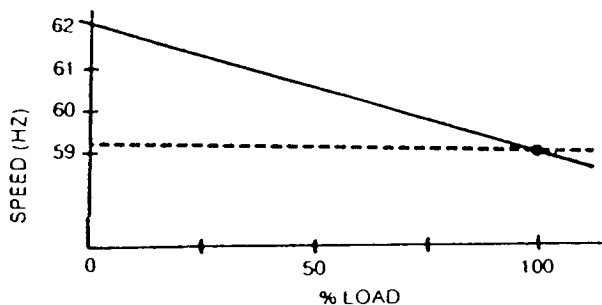


Fig. 12 - Speed vs. Droop

In order to eliminate the speed droop, an integration function is added. This correction function is not only proportional to the amount of speed error but also to the time that the error is present. In this way, the longer the speed error exists, the greater the fuel change made, until the speed error is eliminated and the system runs at the set speed (Ref: Figure 13). This is called isochronous governing.

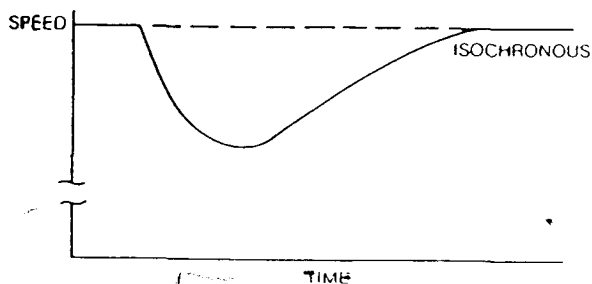


Fig. 13 - Speed vs. droop

By adding an integral function to Figure 9, we now have Figure 14.

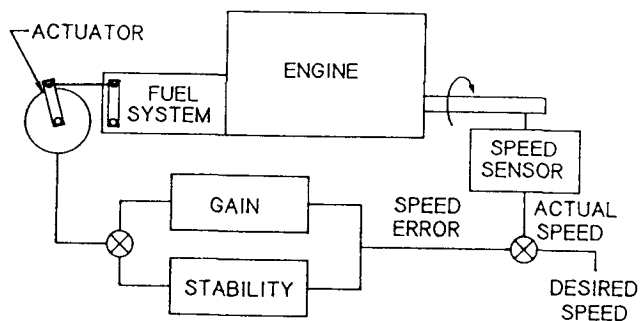


Fig. 14 - PI Control

An integral function is not available on simple fly-weight governors as shown on Figure 1.

Electric speed controllers provide an adjustable integral (stability) function. The amount of integral correction is made by changing the amplification of the integrator part of the electronic circuit. This is achieved by adjusting the potentiometer screw marked STABILITY on the front of the speed control units. Increasing the STABILITY amplification will reduce the time needed for the engine to return to the set speed. Excessive amplification will result in an unstable engine.

The rate of change of the speed error is called the derivative function. The derivative governor corrects fuel delivery as a function of the rate of change of the speed error. Hence, a rapid deviation from the set speed will have a rapid response. On large engines with large actuators, response is slower and speed overshoots can be larger. To correct for this, the setting of a derivative amplifier called DEAD TIME COMPENSATION

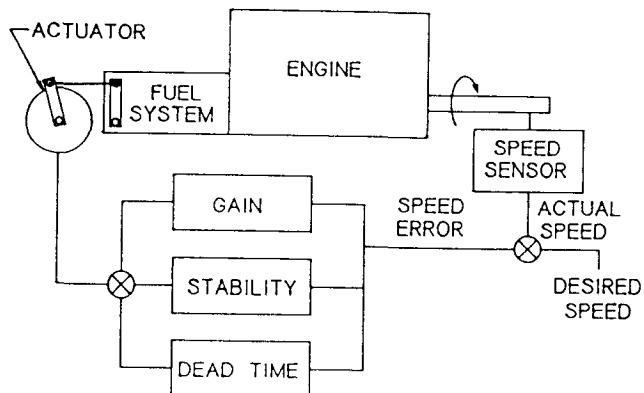


Fig. 15 - PID Control

is increased. This results in a more lively actuator response which reduces the transient speed error during sudden engine load changes.

This derivative function is not available on simple fly-weight governors as shown on Figure 1.

This is achieved on electric speed controllers by changing the value of the DEAD TIME COMPENSATION capacitors which tune the closed loop electronic circuit.

Refer to individual literature for their location and means of adjustment. Excessive DEAD TIME COMPENSATION will result in high frequency instability. Insufficient will result in low frequency surge or speed wandering. The system block diagram is shown on Figure 15.

To summarize electric governor tuning, the three separate adjustments are as follows:

1. The PROPORTIONAL governor function corrects fuel delivery in proportion to the SIZE of the error. It is adjusted with the GAIN setting.
2. The INTEGRAL governor function corrects fuel delivery with respect to the TIME the error exists. It is adjusted with the STABILITY setting.
3. A DERIVATIVE governor corrects the fuel delivery as a function of the RATE of change of the speed error. It is adjusted with the DEAD TIME COMPENSATION.